MAPPING EXPLOSIVE SAFETY HAZARDS (MESH) IN A GIS ENVIRONMENT: A PROGRAM UPDATE

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ABSTRACT

The US Army Engineering and Support Center, Huntsville, has developed an integrated software system called Mapping Explosive Safety Hazards (MESH). This system integrates blast effects prediction software into a Microstation mapping environment. MESH predicts explosive effects and displays hazard distances on a site map. The explosive effects include blast pressures, primary fragmentation, chemical agent dispersal, and the effect of tamping or burial on fragment ranges. MESH provides engineers, planners, and safety professionals with a unique set of tools for rapidly evaluating the potential blast effects hazards at Ordnance and Explosives (OE) remediation sites. Initial versions of MESH became available in 1997. However, MESH is being updated to provide a better user interface and faster execution. MESH is also being revised to match existing OE safety policy for overpressures and fragmentation. The first complete version of MESH will be released in May 1999.

This paper will present an overview of graphical and blast effects prediction capabilities of MESH. Emphasis will be placed on how MESH matches current, DDESB-approved blast effects prediction methods. Specific blast effects software that has been integrated into MESH will be outlined. A live demonstration of MESH will be included in the presentation. Potential uses for both OE projects and other applications will be discussed.

INTRODUCTION

The U.S. Army Engineering and Support Center, Huntsville (USAESCH), is the Corps of Engineers' Center of Expertise and Design Center for Ordnance and Explosives (OE). In this role, the Huntsville Center both sets Army policy and executes OE removal projects at many sites. An important part of planning and executing these projects is, obviously, ensuring the safety of the workforce and the public. In order to meet the needs of the OE site safety planning process, USAESCH has developed an integrated application called Mapping Explosives Safety Hazards, or MESH. This system provides engineers and safety specialists with the ability to do site safety planning and evaluation in a graphically-based, geographical information system (GIS) environment. Initial test versions of MESH became available in 1997. MESH is currently being enhanced in order to provide the optimum user interface; make accurate predictions of blast effects; and provide safety distances that meet U.S. Department of Defense standards and OE safety policy.

This paper describes the changes and enhancements being made to the MESH program. Basic changes in capabilities and system architecture are described first. A recap of how MESH computes the various explosion effects is provided. Each of these sections also discusses the related changes to the user interface. Then, additional user interface changes and enhancements are described.

The reader should note that the details of MESH described herein are based on continuing development efforts. The exact look and feel of the completed version 3.0 of MESH may differ somewhat from what is described below. The reader should also be aware that figures showing MESH palettes and screens have been extracted from a test version of MESH. Therefore, some of the numerical data values and explosion hazard distances in the figures may be incorrect.

MESH PROGRAM CAPABILITIES

MESH is an integrated software system that predicts explosion effects from conventional and chemical ordnance. MESH is essentially a simple GIS. Both the input to the analysis software and the output are integrated with and displayed on a digital map of the OE site. This display permits the user to easily identify hazards to personnel and property, and determine where engineering controls may be required. Explosion effects that MESH can predict include blast overpressures, primary fragments, and chemical agent dispersion. Also, MESH can model the reduction of fragment hazards from intentional detonations effected by burial under soil. The software that predicts these effects uses methods that have been approved by the DOD Explosives Safety Board (DDESB).

MESH SYSTEM ARCHITECTURE

The basic system architecture of MESH remains essentially unchanged. MESH uses the Microstation computer graphics program, developed by Bentley Systems, Inc., and marketed by Bentley and Intergraph Corporation, as the primary graphical user interface. MESH is written as a series of blast effects program modules linked together by a shell written in Microstation Development Language (MDL). This MDL shell collects data from the user, executes the individual modules, and plots the results. MESH is designed to run on either a desktop or notebook personal computer.

Improvements to the system architecture have been implemented in version 3.0. All data is now stored in Microsoft Access database files. There is a permanent link between the Microstation design file and the corresponding database files. Previous versions of MESH used DOS versions of the analysis modules, which resulted in confusing displays and slow execution. The latest version instead uses dynamic linked library, or DLL, versions of these programs. This results in significantly faster execution.

GENERAL USER INTERFACE REVISIONS

MESH version 2.0 used a system of on-screen cards as the user interface. All data entry, execution, and display of alphanumeric results was performed using the cards. This was somewhat cumbersome, as there was an implied order of data entry defined by the cards. Only one card could be open and used at any time. Also, the cards could not be completely dismissed without closing the MESH application. This meant that at times, the open cards blocked view of and access to the site map.

Version 3.0 of MESH has abandoned the use of the card system. Instead, control of the program is provided via a set of tool palettes. Palettes and sub-palettes are essentially a collection of graphical icons or buttons that activate most of the commands in MESH. Most of these buttons open on-screen dialog boxes. All functions and options can be accessed through the main MESH tool palette. This palette contains three sub-palettes for establishing and editing ordnance locations, modifying display symbology, and executing the analysis. These sub-palettes can be operated from within the main palette or dragged off to form separate floating palettes. The main palette also provides access to the munitions database and attachment of the site map files. The MESH main palette and the three sub-palettes are shown in Figure 1.

The Ordnance Location palette provides dialog boxes to add, move, copy, edit and delete ordnance locations on the site map. The Symbology palette provides control of the colors and line styles used to display and label explosion effects contours. The Run palette permits selecting desired overpressure distances and settings for chemical agent calculations, executing the analysis and displaying the results. The tool palette system allows the user to access any or all of the dialog boxes simultaneously, or to dismiss all of them for complete access to the site map without closing MESH. Each dialog box functions exactly as the user would expect for any typical Windows-based application. Each box includes a link to context-specific, on-line help. Version 2.0 included a similar help system. However, the help system in version 3.0 is a complete Windows help application, including an index, links to related help items, and search capability.

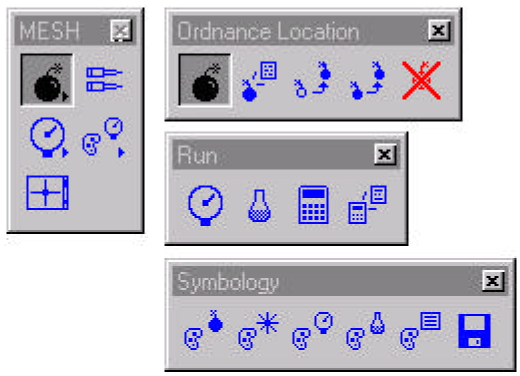

Figure 1. MESH Palettes

ORDNANCE LOCATIONS

After selecting and displaying the site map, the user defines the ordnance and explosives that are to be analyzed by establishing a set of ordnance locations. This is done using the various dialog boxes called from the Ordnance Location palette. Ordnance locations are placed by using the mouse to pick an exact location on the site map. MESH places a numbered symbol at each location. The map coordinates for each location are automatically read from the site map and entered into the database. When each location is placed on the map, the user specifies exactly which ordnance or explosives items are at that location. Each ordnance location can hold any number and type of munitions. Specific munitions are selected from the Munitions Database (MDB). User-defined explosives and ordnance must be entered into the MDB before they can be placed in an ordnance location. The user enters the depth of burial, if any, and soil type in the same Locations dialog box, instead of from a separate card. A typical ordnance location dialog box is shown in Figure 2. This sample shows the definition of an ordnance location that contains three M48 75-mm rounds, buried 1 foot below the ground surface, in wet sandy clay.

Version 2.0 of MESH required the user to access at least two cards simultaneously in order to place ordnance locations. If a user-defined round was desired, a third card would be opened. The operation also required a specific order of commands; first adding the rounds to the card, pressing a button to access the map, then identifying the map location, then exiting the card. Editing, moving and deleting a location used the same set of cards. There was no way to make a copy of an ordnance location; all copies had to be completely entered from scratch. Version 3.0 improves these functions through the tools on the Ordnance Location palette. Adding and editing an ordnance location are both performed in the same Locations dialog box. However, when adding a location, the user can take the appropriate steps in any order, with fewer mouse clicks. When editing the contents of a location, the user selects which location to edit graphically from the map. Moving, copying and deleting ordnance locations are executed by picking the appropriate icon from the Ordnance Locations palette, and then graphically selecting the specific location on the map.

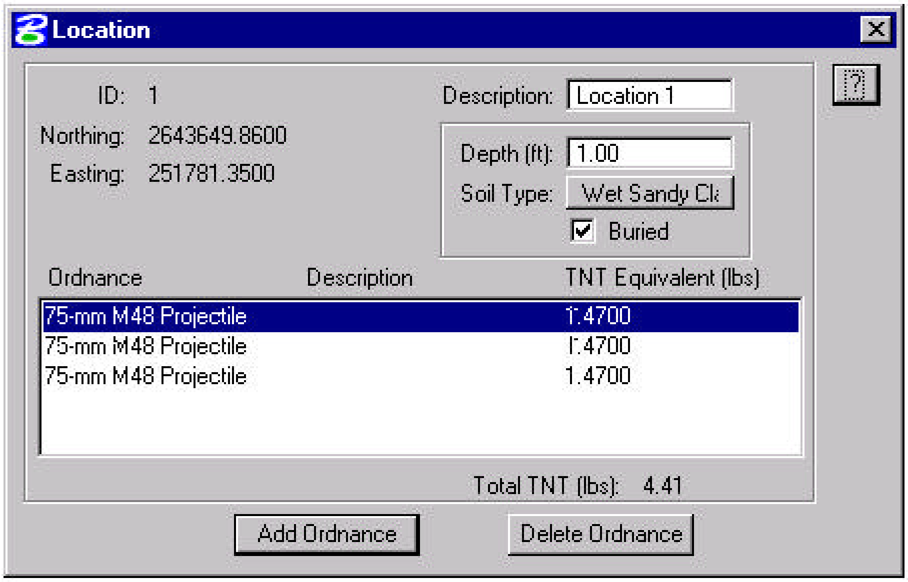

Figure 1. Typical Ordnance Location Dialog Box

MUNITIONS DATABASE

The user defines ordnance at each location by selecting standard items from the Munitions Database (MDB). The munitions currently in the database are listed in Table 1. This is more than twice the number of rounds provided in version 2.0. Also, version 3.0 of MESH includes more detailed data for the munitions, in order to provide more flexibility and accuracy in predicting explosion effects. For each round, the database is expected to include the following information:

- Munition name, including size and type
- Explosive type and weight
- Maximum fragment weight and velocity. These parameters have been computed in accordance with the procedures in HNC-ED-CS-S-98-1 [1], which has been approved by DDESB.
- Information on the cylindrical case model defined in HNC-ED-CS-98-1
- Maximum fragment distance
- Distance to a primary fragment distribution of one hazardous fragment per 600 square foot area. This distance has been computed using the methods in HNC-ED-CS-98-2 [2], which is also approved by DDESB.
- Chemical agent weight and type

The data for standard rounds in the MDB cannot be edited by the user, nor can the standard rounds be deleted from the database. This preserves integrity of the data for specific rounds. The user can create an editable copy of any standard munition or create a new item that is not in the database. However, in order to generate an accurate and complete analysis, the user must enter some or all of the data required for the round. This requires obtaining fairly detailed information about the round, and then applying the procedures in HND-ED-CS-S-98-1 and HNC-ED-CS-S-98-2 to obtain fragmentation information. These methods are not complex, but they generally require expertise in weapons effects to produce reasonable values. Therefore, the data for user-created munitions should be developed by someone with the appropriate experience. In version 2.0 of MESH, the only way to access the MDB was through the cards needed to place ordnance locations. In the revised version, access to the MDB is independent from the entry or editing of ordnance locations. The user accesses the MDB through the Munitions Database dialog box (Figure 3), which is activated from the MESH main palette.

Table 1. Standard Munitions Database

FMU 54A/B Fuze	105 mm M1	8 in M106
20 mm M56A4	120mm M356	250 lb Bomb Mk 81 Mod 1
25 mm M792	3 in Stokes	500 lb Bomb Mk 82 Mod 1
37 mm MK II	3.5" M28A2 Rocket Case	500 lb Bomb M64A1
40 mm MK2	155 mm M107	MK83 Bomb
40 mm HEDP M433	155 mm M122 (Chemical)	MK84 Bomb
57 mm Chinese	4.2 in M3A1	BLU - 109
60 mm M49A3	4 in Stokes	Fragmentation Grenade, M67
75mm M48	4.7 in Mark I	M1A1 Anti-Tank Mine
81 mm M374	5 in 38 Caliber Mk 35	MK II Grenade
2.36 " Rocket (Case Only)	165 mm M123 Series	16" Mk 14 Projectile
2.75" M229 Rocket	175 mm M437 Series	4 lb Frag Bomb M83

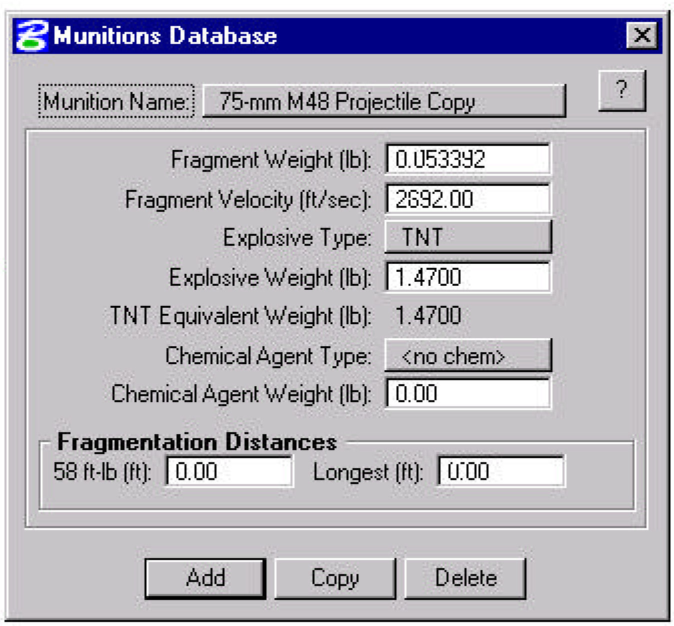

Figure 3. Munitions Database Dialog Box

OVERPRESSURE MODULE

The Ovepressure Module in MESH remains essentially unchanged in version 3.0. The Overpressure Module uses the Kingery curve equations [3], which are approved equations for predicting blast pressures used in TM 5-1300 [4] and other references. The module computes overpressures based on a bare hemispherical surface burst, ignoring any reduction in the effective charge weight caused by the energy required to shatter the weapon case.

The user selects which overpressures to calculate using the Overpressure Settings dialog box, reached from the Run palette (Figure 4). This dialog box provides the same functions as were included on the overpressure card in version 2.0, but in a Windows-consistent format. The user chooses which overpressures are of interest by selecting from a list of standard explosive safety quantity distances (Q-Ds). Both standard U.S. and NATO Q-Ds are available. The user may select one, several or all of these values. The user also has the option to specify other overpressure levels, in pounds per square inch (psi). Of particular interest for OE projects are K50, or Inhabited Building Distance, and K328, or Temporary Threshold Shift Distance. The K50 distance corresponds to an overpressure level of 0.9 psi, and is the pressure distance used to determine personnel separation distance (PSD) for accidental explosions. The K328 distance corresponds to a pressure level of 0.065 psi, and is the distance used for overpressure for public withdrawal distance (PWD) from intentional detonations.

For each donor position, MESH computes the distances to all of the specified overpressure levels. MESH assumes that the total charge weight in each ordnance location detonates simultaneously. Since the distances are based on total charge weights, they can vary for different locations. Therefore, rather than store these distances for each round in the MDB, MESH computes them for each ordnance location for every execution. MESH plots the overpressure distances as a set of concentric contours centered on each donor location. Each contour can be labeled with the applicable K value and/or title, overpressure, and distance.

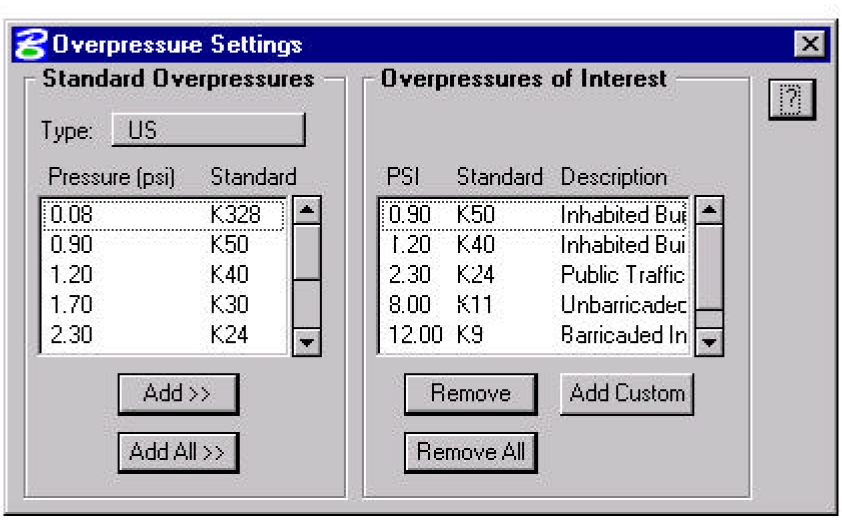

Figure 4. Overpressure Settings Dialog Box

FRAGMENTATION MODULE

The Fragmentation Module has been significantly enhanced in version 3.0 of MESH. Version 2.0 computed two fragment ranges. One was the maximum fragment range. The other was and the range to the farthest thrown hazardous fragment, where a hazardous fragment is defined as one with an impact energy of 58 ft-lb. Version 3.0 still predicts the maximum fragment range. It also determines the range to a distribution of no more than one hazardous fragment per 600 square foot impact area. This is the minimum level of personnel protection from fragmentation required by DOD Ammunition and Explosive Safety Standards, DOD 6055.9-STD [5]. In MESH this distance is called the Hazardous Fragment Range. These two distances are of particular interest on OE projects. The maximum fragment range is used in determining Public Withdrawal Distance for both intentional and unintentional explosions. The hazardous fragment range is used in establishing the Personnel Separation Distance for unintentional detonations.

Version 2.0 computed the fragmentation distances for each munition, every time MESH was run. In version 3.0 the two fragment distances have been stored in the MDB for each standard munition. For ordnance locations that contain only one standard round, therefore, MESH simply performs a table lookup to determine and plot the distances. For user-defined munitions, if the user has provided the precomputed distances, then the table lookup is performed. If these distances have not been provided, then the user must provide data on the cylindrical case model defined in HNC-ED-CS-S-98-1. MESH uses this data and the HAZFRG program [2] to compute the maximum fragment weight and velocity for each segment of the round. It then uses the trajectory program TRAJ [6] to calculate flight trajectories and the maximum fragment range. The HAZFRG program also provides the hazardous fragment range.

For an ordnance location that contains more than one round, the process is more complex. The maximum fragment range for that location is the largest of the individual maximum fragment ranges for each round in the location. The hazardous fragment range must be computed using the HAZFRG program, using a combination of the cylindrical case model data for each round.

Version 2.0 included a separate on-screen card to control the Fragmentation Module. However, version 3.0 requires no specific input other than munitions data. Therefore, there is no corresponding dialog box.

BURIED EXPLOSION MODULE

MESH includes the ability to evaluate the effect of burial, or earth tamping, on the primary fragments from a munition. This permits the user to evaluate the depth of burial that may be required to reduce the fragment hazard distances from an intentional detonation. While this capability was included in version 2.0, it required the use of two separate computer programs. Version 3.0 performs these calculations using a revised edition of the Buried Explosion Module (BEM), which performs the entire calculation in one program. The BEM program, and its underlying procedures, are documented in HNC-ED-CS-S-97-7, Revision 1 [7]. These procedures have been approved by DDESB. Inputs to BEM include the maximum fragment weight and velocity for each round, and the total explosive charge weight in the ordnance location. The BEM program determines the characteristics of the crater caused by the detonation. It then computes the residual velocity of the maximum fragment as it exits the earth cover. This residual velocity is then used with the fragment weight to compute the maximum fragment distance. Again, the TRAJ program is used to determine this distance. BEM also calculates the soil ejecta distance, which is the maximum range that the earth cover will be thrown by the explosion. This distance is important, because sufficient burial can reduce the maximum fragment range to be less than the soil ejecta distance. In this case, the soil ejecta distance must be used as the maximum fragment range for safety planning. It should be noted that MESH will not compute a Hazardous Fragment Distance for a buried explosion. The use of burial as an engineering control implies an intentional detonation, so the Hazardous Fragment Distance is meaningless for a buried explosion. Additionally, computing a fragment distribution for a buried explosion would require calculating the actual fragment range for every fragment produced, which would be unnecessarily computationally intensive.

For ordnance locations with user-defined rounds, the BEM cannot be executed unless either the maximum fragment weight and velocity, or the munitions case model, have been provided. For locations with multiple rounds, BEM uses the total charge weight to determine cratering. It then computes a reduced maximum fragment range for each round. The maximum fragment range for that location is the largest of the ranges for all rounds.

CHEMICAL AGENT MODULE

The Chemical Agent Module is in version 3.0 of MESH is essentially unchanged. It based on the computer program D2PC [8]. This program predicts hazardous chemical agent dispersion ranges. These are the No Significant Effect (NOSE), 0% lethality and 1% lethality ranges. D2PC normally requires significant input about the site and meteorological conditions. In order to develop this input, the user normally would need a high level of expertise. However, most of the input to D2PC has been programmed into MESH. The user is required only to input three parameters: wind speed, temperature, and mixing height. These parameters apply to all ordnance locations for a given MESH application.

Version 2.0 included an on-screen card to control which chemical agent hazard contours were to be plotted and make selections of site conditions. For version 3.0, a simplified Chemical Settings dialog box is accessed from the Run palette. This box still permits entry of the site conditions, but all three hazard distances are now automatically calculated for each MESH run.

It should be noted that, because of the pre-programmed input values, MESH computes chemical agent dispersal ranges that are approximate and should only be used as guidelines. However, since the pre-programmed input to D2PC includes certain assumption, the hazard distances may not be entirely applicable to the site being considered. At this writing, MESH should not be used to determine safety requirements for chemical weapons but, instead, should be used to identify potential problem areas for which a more detailed analysis using D2PC is required. Future development of MESH will address the issue of improving the accuracy and applicability of chemical agent hazard results. This may include a more complete integration of D2PC such that all input parameters can be entered by the user.

PROGRAM EXECUTION AND RESULTS DISPLAY

MESH version 2.0 provided execution through an output control card. This card has been replaced with the Run dialog box, initiated from the Run tool palette. The dialog box includes a run log that is visible during execution of the analysis modules and contains all interim results. This log file can be saved to disk and printed for review. The Run dialog box also contains a status bar to show progress of the analysis.

On-screen display of alphanumeric results has been revised. In version 2.0, most results were displayed on their associated cards. For example, to see the fragmentation results in numerical form, the user had to return to the fragmentation card. In version 3.0, display of the results is provided using the Results dialog box, activated from the Run palette. This box provides a table of the overpressure results and a listing of all fragmentation, soil ejecta and chemical distances for a given ordnance location. The user opens this dialog box, then picks the an ordnance location using the mouse to populate the fields in the dialog box. Printing of results is now provided by a reports module, which generates an ASCII file containing the complete problem input for each ordnance location and analysis results.
A typical MESH site map display after the analysis has been executed, with overpressure and fragment contours, is shown in Figure 5.

Version 3.0 includes a number of enhancements to the display. All display of results is now dynamic. Rather than being automatically written into the Microstation design file, all results are stored in memory and displayed over the site map. The user can now explicitly command MESH to “permanently” write the graphical results to the file. This is done using the Write Symbology dialog box. Once the results are written to the design file, the Microstation plotting and printing routines can be used to produce a hard copy. The dialog box also provides the option to remove the results from the file. The results do not disappear, but they return to dynamic storage.

Text labels on each hazard contour are now dynamically scaled with respect to the size of the screen, rather than in a fixed text size in the Microstation file. Thus, when the user zooms in or out of a display, the text sizes remain the same relative to the screen. This lets the user zoom in sufficiently to clearly see both the hazard contours and their associated labels. The on-screen legend has been revised for version 3.0. The legend is now a typical chart-type legend. It is also dynamically stored and dynamically scaled on the screen.

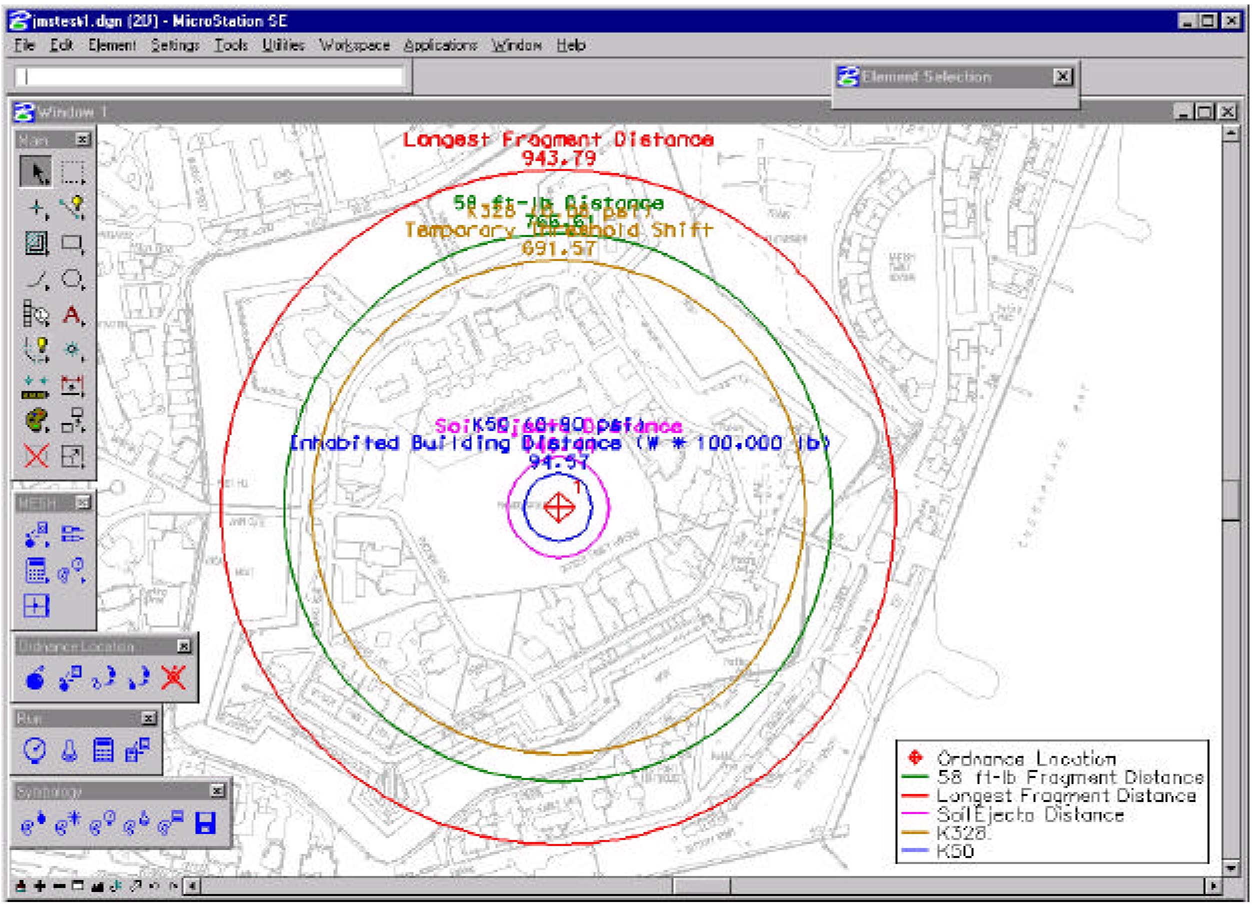

Figure 5. Typical MESH Results

The Symbology palette also provides dialog boxes to control the symbology, or line weights, styles, and colors, for the ordnance location symbols; overpressure, fragmentation and chemical hazard contours; and the legend. For example, a typical Overpressure Symbology dialog box is shown in Figure 6. For each overpressure contour, options include visibility (on or off), labels on or off, short labels as opposed to full labels, text size, and the color, style and weight of the contour. These options can be defined for individual contours or globally for all. There is an option to use black and white display, rather than color, for printing to black and white laser printers. Also, there is a button to return to the a standard, default symbology predefined in MESH.

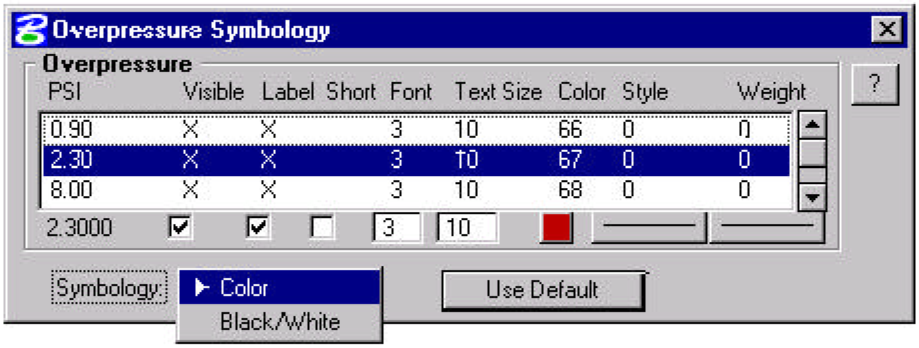

Figure 6. Overpressure Symbology Dialog Box

CURRENT STATUS AND DISTRIBUTION OF MESH

The revisions and enhancements discussed above are being implemented during the first half of 1999 by USAESCH and Montgomery Watson, Inc. As stated previously, some of the details of various screens, dialog boxes, and calculations may differ in the actual software. However, the basic capabilities described above will all be included in MESH. We anticipate completion of a releasable version in late May 1999. This will be the first version intended for wide release to Government agencies and contractors. The MESH executable codes may be available on the USAESCH Internet Web Site later in 1999.

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